# Comparison of marketed Gadolinium-based Contrast Agents Relaxivities on Clinical MR scanner at 1.5T, 3T and 7T in water and plasma for a large range of physiological concentrations

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**Target audience:** MR Physicists, Clinicians

**Purpose:** Several papers reported contrast agent (CA) relaxivity measurements at several clinical magnetic fields [1-2]. None have investigated them on a large physiologically relevant range including first pass equivalent concentrations. Thus B1 and B0 heterogeneities make this data difficult to extract at Ultra High Field (UHF). In this work, using state of the art relaxometry methods, we measured r1 and r2 as a function of B0 (1.5, 3 and 7T) for a large CA concentration window.

**Materials and Methods:** On Magnetom 7T, Trio 3T and Avanto 1.5T (Siemens Healthcare, Erlangen, Germany) MRI scanners, we acquired T1 and T2 maps using birdcage circular polarized transceiver coils. Forty eight 10 mL vials of distilled water and plasma (Seronorm, Sero, Billingstad, Norway) were prepared at the 8 CA concentrations between 0 to 10 mmol/L. Four contrast agents were tested: Gadoterate Meglumine (Dotarem), Gadopentetate Dimeglumine (Magnevist), Gadobutrol (Gadovist), Gadobenate Dimeglumine (Multihance),, Gadoteridol (Prohance), Gadodiamide (Omniscan). Samples were placed in a rack, inside an isotherm polystyrene box, covering a 200x200 $mm^2$-FOV, in a salted water bath to limit B0 and B1 heterogeneities. The water bath was pre-heated to ~40°C before being poured into the box. An optical thermal probe was positioned in the bath to control temperature during the whole experiments and data was recorded using "Evolution" Fiso Technologies software. In the box, temperature decreased by less than 1°C/hour. Experiences were launched when the temperature inside the box was 37.5°C.
For T1 mapping, we used the VAFI approach [3]: 3D AFI and GRE images were both acquired in strong spoiling regime with the same 1.5x1.5x3 $mm^3$ voxel volume. With a fixed 10ms-TR, the GRE sequence was repeated with flip angles 4, 5, 6, 8, 11, 15, 20, 26, 33, 41, 50° in order to be sensitive to a wide T1-range. For T2 mapping, we used a robust Spin Echo approach [4] with segmented EPI readout [5]: one slice was acquired with a 0.5x0.5x8 $mm^3$ voxel volume and with ETL=3 and TR=2000ms; TEs were spaced from 10 to 316 ms along a log scale. The total exam time was around 55 min per B0-field and per solvent. T1 and T2 analysis was performed on Matlab (Mathworks, USA).

**Results:** Fig.1 shows $r_1$ and $r_2$ changes with increasing CA concentrations in plasma at 7T corresponding to the most challenging conditions in terms of field inhomogeneities. The dependence of $r_1$ and $r_2$ on the magnetic field strength is presented in Tables 1 and 2.

**Discussion and conclusion:** Our study explored a larger CA physiological concentration range than previously reported. It demonstrated a linear behavior as expected on the whole window of interest [1, 2]. This sustains the hypothesis of a robust $T_1$ and $T_2$ extraction even at the highest magnetic field. Our $r_1$ results were also in good agreement with those reported last year by other investigators [6]. Once into plasma, Multihance and Gadovist show a stronger $r_1$ and $r_2$ increases compared to the other CA. This is typically attributable to a protein-binding of these CA, which is known for Multihance but has not yet been reported for Gadovist. Finally, our results confirm that contrast-enhanced MR angiography could take advantage of UHF because of CA $r_1$'s decay lower than biological tissues' and weak $r_1/r_2$ change compared to lower field [7, 8].

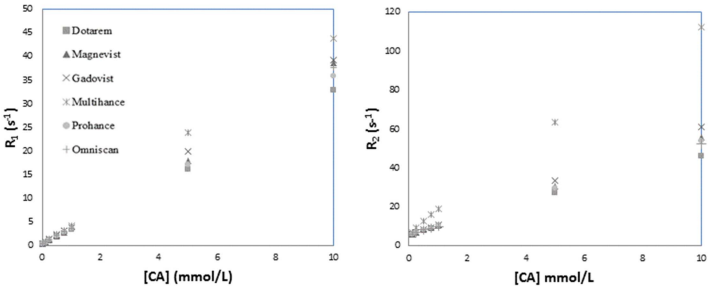


*Fig.1: $R_1$ and $R_2$ extractions obtained for the 48 samples of various CA at 7T in plasma solvent at 37°C*

*Tables 1 and 2: $r_1$, $r_2$ in $s^{-1}.(mmol/L)^{-1}$ and $r_1/r_2$ for several marketed CA at 1.5, 3 and 7T respectively in distilled water and plasma at 37°C*

| B0 (T) | 7.0 | | | 3.0 | | | 1.5 | | |
|---|---|---|---|---|---|---|---|---|---|
| CA | $r_1$ | $r_2$ | $r_1/r_2$ | $r_1$ | $r_2$ | $r_1/r_2$ | $r_1$ | $r_2$ | $r_1/r_2$ |
| Dotarem | 2.73 | 3.43 | 0.80 | 2.80 | 3.66 | 0.765 | 3.00 | 3.79 | 0.79 |
| Magnevist | 3.02 | 4.13 | 0.73 | 3.17 | 4.36 | 0.727 | 3.20 | 4.24 | 0.75 |
| Gadovist | 2.81 | 3.75 | 0.75 | 3.02 | 4.08 | 0.740 | 3.16 | 4.20 | 0.75 |
| Multihance | 3.63 | 4.78 | 0.76 | 3.77 | 4.98 | 0.757 | 4.06 | 5.11 | 0.79 |
| Prohance | 2.69 | 3.40 | 0.79 | 2.76 | 3.80 | 0.726 | 2.84 | 3.83 | 0.74 |
| Omniscan | 2.87 | 3.80 | 0.76 | 3.08 | 4.36 | 0.706 | 3.06 | 4.13 | 0.74 |

| B0 (T) | 7.0 | | | 3.0 | | | 1.5 | | |
|---|---|---|---|---|---|---|---|---|---|
| CA | $r_1$ | $r_2$ | $r_1/r_2$ | $r_1$ | $r_2$ | $r_1/r_2$ | $r_1$ | $r_2$ | $r_1/r_2$ |
| Dotarem | 3.00 | 4.25 | 0.71 | 3.29 | 4.83 | 0.68 | 3.49 | 4.97 | 0.70 |
| Magnevist | 3.48 | 4.82 | 0.72 | 3.90 | 5.33 | 0.73 | 4.11 | 5.30 | 0.78 |
| Gadovist | 3.71 | 5.37 | 0.69 | 4.28 | 6.20 | 0.69 | 4.49 | 6.09 | 0.74 |
| Multihance | 4.05 | 12.36 | 0.33 | 5.29 | 14.33 | 0.37 | 6.68 | 14.30 | 0.47 |
| Prohance | 3.14 | 4.68 | 0.67 | 3.52 | 5.35 | 0.66 | 3.70 | 5.36 | 0.69 |
| Omniscan | 3.38 | 4.34 | 0.78 | 3.67 | 5.17 | 0.71 | 3.77 | 5.09 | 0.74 |

**References :** [1] Rohrer et al. Invest Radiol 2005; 40:715-724 ; [2] Noebauer-Huhmann et al. Invest Radiol 2010;54:554-558 ; [3] Hurley et al. Magn Reson Med 2012; 68:54-64; [4] Young I.R., et al. J Comp Assist Tomogr 1982; 6: 1-18 ; [5] Duhamel G. et al. Proc. Intl. Soc. Mag. Reson. Med. 2012;20:446; [6] Vander Elst L. et al. Proc. Intl. Soc. Mag. Reson. Med. 2013; 21: 746; [7] Pinker-Domenig K et al. Proc. Intl. Soc. Mag. Reson. Med. 2013; 21: 3375; [8] Rooney W et al. Proc. Intl. Soc. Mag. Reson. Med. 2013; 21: 1224;